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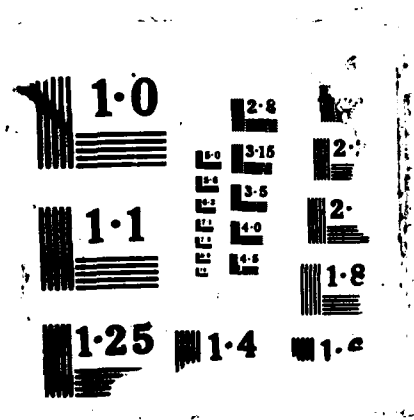
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THE ANALYSIS OF DATA FOR  
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19. ABSTRACT (Continue on reverse if necessary and identify by block number) Proposals were made by TEDECO, the chip detector contractor, to increase the power of the chip detector system installed in UH-60A aircraft by approximately six fold. The work described is an effort to determine what, if any, effects this might have on the lubricant. A test lubricant system was constructed consisting of an oil sump, test lubricant pump and wear metal generator, and a TEDECO Model E1103H Zapper console and A615 full flow debris monitor. Several MIL-spec oils were received for test. Following the determination of baseline physical and chemical properties, including an in-house developed technique for determining the chemical composition, test runs were made simulating actual operating condition. In addition, a small sample of the test oil was subjected to 1000 zaps, at operating temperature, by the manual addition of metal particles, to concentrate the zapper effect. Following the tests, the used oils were analyzed and compared to the pre-test results. None of the tests could detect any significant changes in the oils due (continued on reverse)					
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to the operation of the chip detector. However, in several cases, with the wear metal generator operating, a black, sludgelike material formed in the gap around the detector rendering its "zapping" function inoperative. An unsolicited proposal has been submitted to the Commander, USA-AVRADCOM for further study of this problem.

→ Key words →

### EXECUTIVE SUMMARY

Proposals were made by TEDECO, the chip detector contractor, to increase the power of the chip detector system installed in UH-60A aircraft by approximately six fold. The work described is an effort to determine what, if any, effects this might have on the lubricant.

A test lubricant system was constructed consisting of an oil sump, test lubricant pump and wear metal generator, and a TEDECO Model E1103H Zapper console and A615 full flow debris monitor. Several MIL-spec oils were received for test. Following the determination of baseline physical and chemical properties, including an in-house developed technique for determining the chemical composition, test runs were made simulating actual operating condition. In addition, a small sample of the test oil was subjected to 1000 zaps, at operating temperature, by the manual addition of metal particles, to concentrate the zapper effect.

Following the tests, the used oils were analyzed and compared to the pre-test results.

NONE OF THE TESTS COULD DETECT ANY SIGNIFICANT CHANGES IN THE OILS DUE TO THE OPERATION OF THE CHIP DETECTOR.

However, in several cases, with the wear metal generator operating, a black, sludgelike material formed in the gap around the detector rendering its "zapping" function inoperative. An unsolicited proposal has been submitted to the Commander, USA-AVRADCOM for further study of this problem.



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## INTRODUCTION

The transmission chip detector system installed in UH-60A aircraft is composed of "fuzz burn-off" type chip detectors. Large conductive particles that are not burned off and remain in the chip detector gap after the capacitor discharges will result in an indication of a chip.

Proposals were made by (TEDECO), the chip detector contractor, which would result in an approximate six-fold increase in the energy available for the "fuzz burn-off" function. The increase in available energy is intended to improve the ability of the detector to burn-off multiple bridge points in the gap caused by the small unburned conductive particles. With the proposed change, the energy level of the input module and main sump chip detectors will increase from .015 joules to .084 joules. Energy level of the accessory module detectors will increase from .007 joules to .042 joules.

Concern was expressed about the impact arcing may have on the lubricating properties of the oil and possible contaminant by-products in that system. There appeared to be a lack of information on the result of the arcing and this work is an effort to determine what, if any, effects operation of the chip detector would have on the lubricant.

## APPROACH

In order to examine the effects that operation of the chip detector could have on a lubricant, it would be necessary to simulate chip detector operating conditions in the laboratory. This would necessitate construction of a rig which would be capable of oil sump temperature control, wear particle generation, controlled circulation of the oil, and incorporation of a chip detector model actually in current use in aircraft.

Several military-specification lubricants were chosen for test as being representative of the chemical types of oils presently in use. The oils

would be subjected to a battery of chemical and physical tests, both ASTM and in-house developed methods, to characterize them and establish baseline values. Following a test run, the used oil would be reanalyzed in an attempt to determine if any changes had taken place and, if so, what those changes might be.

Operating test conditions would be controlled so that the various test parameters, i.e., temperature, circulation, and metal particles, could be controlled.

#### EXPERIMENTAL

A test lubricant system was fabricated and assembled. The system consisted of an oil "sump", test lubricant pump and wear-metal generator with variable speed motors, and a TEDECO Model E1103H Zapper console and A615 full flow debris monitor. Initial shakedown testing with a recirculating lubricant system was accomplished with the following conditions:

Test duration	24 hrs. <sup>3</sup>
Lubricant charge	2300 cm <sup>3</sup>
Sump lubricant temp.	300°F
Flow thru detector	500 cm <sup>3</sup> /min
Burn-off energy	0.094 joule
Wear specimens	AMS 9310

The wear specimen material selected for the study was a typical turbine engine gear steel which was obtained in the annealed state to promote wear. The lubricant employed for the shakedown phase was Mobil Jet II, a lubricant qualified to MIL-L-23699 but not believed to be widely used within the military services.

The initial 24-hour run was completed without incident but the chip detector did not indicate a single burnoff. The test lubricant at 24 hours showed moderate degradation as evidenced by viscosity and acid number increase (Table 1), along with significant darkening of the fluid. Inspection of the detector gap revealed a black gel, completely filling the gap. There were no particles of a size sufficient to bridge the gap. One such particle



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TABLE 1. INITIAL 24-HOUR OPERATION LUBRICANT ANALYSIS

<u>Sample</u>	<u>TAN</u>		<u>Vis @ 40°F</u>	
	<u>0 hr</u>	<u>24 hr</u>	<u>0 hr</u>	<u>24 hr</u>
Mobil Jet II	0.80	1.43	24.7	26.0

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placed across the gap would not activate a discharge until subsequent removal of the adhering gel.

Examination of the lubricant sump after the test revealed a broad range of wear particles present. It appeared that the wear-metal generator was performing as expected. The question as to whether the geometry of the system allowed for particle delivery to the detector was eliminated by a reconfiguration of the system to insure delivery to the detector. Noticeable deterioration of the test lubricant was unexpected since the fluid should be quite stable at the conditions employed (but without wear). Closer examination of analysis data indicated the lubricant might have undergone degradation in storage. The initial acid number, before test, was 0.80 mg KOH/g. This value was 0.07 mg KOH/g in 1970. The product is available locally and a fresh supply was ordered for subsequent work.

Although the fresh lubricant supply was expected to exhibit greater stability, it was planned to reduce the sump temperature to 200°F for the next run in order to lower the masking effects of oxidative deterioration.

Several oil samples were received from the military supply system. MIL-L-23699C oils by Bray, HATCO, American Oil and Supply and Emery/Royco arrived and baseline data such as viscosity, total acid number and detailed chemical composition were obtained before actual testing with the burn-off chip detector began (Tables 2 and 3). Comparison of detailed chemical composition could reveal essentially identical oils which would eliminate some duplicate

TABLE 2. ANALYSIS OF TEST OILS AS RECEIVED

<u>Sample</u>	<u>Source</u>	<u>Vis @ 40°C</u>	<u>Vis @ 100°C</u>	<u>%P (XRF)</u>	<u>TAN</u>
ME-171	Bray	26.86 cs	5.15 cs	0.17	0.0
ME-172	HATCO	25.80 cs	5.07 cs	0.19	0.0
ME-180	American	25.37 cs	5.01 cs	0.17	0.0
ME-181	Emery	24.92 cs	5.03 cs	0.14	0.16
ME-182 (used)	Blackhawk	23.71 cs	4.80 cs	0.19	0.46

CHARACTERIZATION OF OIL PARTICULATES BY XRF (PPM)

	<u>ME-171</u>	<u>ME-172</u>	<u>ME-180</u>	<u>ME-181</u>	<u>ME-182</u>
Mg	0.23	0.31	0.21	0.33	0.29
Al	0.40	--	--	--	--
Si	--	--	0.15	0.21	--
S	--	--	--	--	0.21
Cl	0.52	0.86	0.42	0.86	0.71
Fe	0.08	--	--	--	0.17
P	--	--	--	0.15	--

testing. In addition, a 5 gallon sample of a used oil from a Blackhawk helicopter transmission was received. This sample was tested along with the new oils.

Chemical analysis determined the composition of the as received oils and established baseline values for each oil (Table 3). The analysis revealed that ME-172 (HATCO) and ME-180 (American) were essentially the same. The initial test using the new Mobil Jet II oil was run with a sump temperature of 300°F and continued for 40 hours with a total of five capacitor discharges.

TABLE 3. CHEMICAL COMPOSITION OF TEST OILS

	Bray ME-171 %	HATCO ME-172 %	American ME-180 %	Emery ME-181 %	Black(3) Hawk ME-182 %	Mobil ME-184 %
<u>MONO-ACIDS</u>						
C <sub>5</sub>	38	21	25	25	15	21
C <sub>6</sub>	Trace	2	Trace	16	2	2
C <sub>7</sub>	5	33	33	24	25	50
C <sub>8</sub>	6	22	22	7	32	2
C <sub>9</sub>	41	Trace	---	26	Trace	26
C <sub>10</sub>	9	21	20	4	24	Trace
<u>Polyols</u>						
TMP					100	
PE	100	100	100	100		90
DPE						10
<u>Additives</u>						
PANA(1)	X					
Van- 81(2)	X	X	X	X	X	X lube
<u>DI-ACIDS</u>						
C <sub>5</sub>	(4)	(4)				
(1) 1-phenyl- $\alpha$ -naphthylamine (2) p,p'-dioctyldiphenylamine (3) Received used (4) Not confirmed						

At this point, the wear generator was disassembled and the gear steel specimens replaced with mild steel (QQ-S-698, grade 1009) coupons. The run was then restarted and 14 discharges (19 total) were counted in the time frame of 40 to 43.5 hours. At the latter time, a chip light indication was noted without subsequent burnoff. The run was consequently terminated.

Acid number and viscosity results on the lubricant did not indicate any significant gross deterioration of the oil (Table 4).

TABLE 4. ANALYSIS OF MOBIL JET II - INITIAL TEST - 300°F

<u>Sample No.</u>	<u>Test Time, Hr.</u>	<u>Total Acid No., mg KOH/g</u>	<u>Viscosity 40°C, cSt</u>	<u>No. of Zaps</u>
ME-184	0	0.03, 0.02 <sup>(1)</sup>	24.64	0
ME-185	40	0.10, 0.11 <sup>(1)</sup>	24.84	5
ME-186	43.5	0.08, 0.09 <sup>(1)</sup>	24.87	19

GAS CHROMATOGRAPHIC ANALYSIS

<u>MONO-ACIDS</u>	<u>ME-184 %</u>	<u>ME-185 %</u>	<u>ME-186 %</u>
C <sub>5</sub>	21	21	26
C <sub>6</sub>	2	2	1
C <sub>7</sub>	50	51	49
C <sub>8</sub>	2	1	1
C <sub>9</sub>	26	24	22
C <sub>10</sub>	Trace	Trace	Trace
C <sub>11</sub>	Trace	Trace	Trace

(1) Repeat test with different personnel and equipment.

The second acid number value was performed as a repeat test using a modified method with different equipment and personnel. The close values indicate the significance of the data and the reproducibility of the procedures. The values for ME-185 and ME-186 are real and amount to the production of the

equivalent of approximately 42 milligrams of pure acetic acid per pint of oil. This is about two drops of pure acetic acid, which is significant.

The three lubricant samples were also analyzed by high resolution gas chromatography using chemical techniques to distinguish between free acids which may have been "generated" and acyl groups in the ester structure of the lubricant. Comparison of the baseline analysis (ME-184) to the 40- and 43.5-hour samples (ME-185 and ME-186) indicates that some change or degradation has taken place (Table 4). The analysis for free acids does not show the presence of detectable amounts of free organic acids. However, the GC data does show the presence of "new" materials and components not present in the fresh oil. These materials have not been identified.

A repeat test with the Mobil Jet II lubricant was performed identical to the previous run except that the chip detector was not energized. The intent was to separate the effects of detector burnoffs and thermal/oxidative degradation of the lubricant. The two tests were identical to the degree that AMS 9310 wear specimens were utilized up to 40 hours of test time and, as with the initial test, mild steel wear specimens were present during the period of 40 to 43.5 hours.

Test results comparing both runs indicates only slight property changes (Table 5). The test without detector activation actually resulted in somewhat greater fluid deterioration as evidenced by acid number and viscosity. This was probably due to differences in the amount of catalytic wear introduced into the lubricant system during test. In the initial determination, wear of the 9310 specimens was nil through 40 hours. Wear of the mild steel specimens totalled 0.6 g in the test period of 40 to 43.5 hours. In contrast, the baseline test (detector de-energized) resulted in gear steel wear of 0.5 g through 40 hours and mild steel of 0.2 g during the run remainder. It is to be expected that the increased wear with 9310 steel in the latter case would account for increased lubricant degradation. Thus, for this test lubricant, it is concluded that any "zapper" effect is masked by the inherent variance of the experiment.

TABLE 5. COMPARISON OF TEST RESULTS  
DETECTOR ENERGIZED VS. DETECTOR DE-ENERGIZED

<u>Sample No.</u>	<u>Test Time, Hr.</u>	<u>TAN, mg KOH/g</u>	<u>40°C Vis., cSt</u>	<u>No. of Zaps</u>
<u>Mobil Jet II</u>				
<u>Detector Energized</u>				
ME-184	0	0.03, 0.02	24.64	0
ME-185	40	0.10, 0.11	24.84	5
ME-186	43.5	0.08, 0.09	24.87	19
<u>Detector De-Energized</u>				
ME-185 (1-4)	40	0.15	25.13	0
ME-186 (2-4)	43.5	0.15	25.17	0
<u>Detector Energized</u>				
<u>HATCO</u>				
ME-172	0	0.00 (baseline)		
ME-172	30	0.02		
ME-172	48	0.05		

In order to "concentrate" the effect of the zapper in an attempt to overcome the thermal/catalytic effects of the experiment, a small oil sample, approximately 20 cc, was placed in a glass vial with the zapper fitted to it. The oil was heated to operating temperature (200°F) and fine iron particles were dropped in with the zapper energized. More than 1000 zaps were generated for each oil. The same test procedure was followed with the zapper de-energized. Table 6 lists the TAN and TBN results for all the oils except the HATCO. Since the HATCO oil was tested in the full chip detector rig, the American Oil was used for the concentration test. Both oils show the same composition by chemical characterization (Table 3). The Blackhawk oil was obtained used and was not included in this test.

NONE OF THE TESTS COULD DETECT ANY SIGNIFICANT CHANGES IN THE OILS DUE TO THE OPERATION OF THE CHIP DETECTOR.

TABLE 6. CONCENTRATION EFFECTS COMPARISON OF TEST RESULTS

<u>Sample No.</u>	<u>Source</u>	<u>TAN*, mg KOH/g</u>	<u>TBN*, mg KOH/g</u>
<u>Detector Energized - 1000 Zaps</u>			
ME-171	Bray	0.00	0.00
ME-180	American	0.01	0.00
ME-181	Emery	0.12	0.00
ME-184	Mobil	0.04	0.00
<u>Detector De-Energized</u>			
ME-171	Bray	0.01	0.00
ME-180	American	0.01	0.00
ME-181	Emery	0.13	0.00
ME-184	Mobil	0.04	0.00

\* ASTM D-664

## ANALYTICAL METHODOLOGY

Tests for Total Acid Number (TAN), Total Base Number (TBN), and viscosity were according to ASTM procedures as follows:

<u>Test</u>	<u>Method</u>
TAN	ASTM D-664
TBN	ASTM D-664
Viscosity	ASTM D-445

The analysis to characterize the chemical composition of the oils is done by gas chromatography following a one-step chemical treatment to "break down" the oil into its component parts. Initially, the neat oil is transesterified with reagents that break the ester bonds to yield the free alcohols and the methyl ester at the liberated organic acids. Milligram amounts of oil are used, and the reaction mixture is analyzed directly without any additional treatment. Gas chromatographic analysis utilizing capillary and/or packed columns shows the chemical composition of the acids comprising the

oil basestock. If the alcohol is trimethylolpropane, it will remain soluble in the reaction mixture. If pentaerythritol or dipentaerythritol is present, they will form a precipitate. Those alcohols are then determined by a derivatizing technique involving silylation and then gas chromatography. In addition, some additives such as PANA (1-phenyl- $\alpha$ -naphthylamine) and Vanlube 81 (p,p'-dioctyldiphenylamine) may also be determined directly.

To determine whether free acids are present to begin with in the untreated oil, a technique is used utilizing chemical reagents which will only esterify the free acids and not break down the oil. This technique was used on the oils following their use in the chip detector rig, along with the complete chemical characterization techniques.

#### CONCLUSIONS

Tests of two different turbine oils, Mobil Jet II (ME-184) and HATCO (ME-172), in the chip detector rig failed to show any degradation of the test oil due to arcing of the detector. The wear metal generator operated as expected and the test oils did receive a number of zaps.

Using a small oil sample and producing approximately 1000 zaps also failed to show any degradation of the oil due to arcing. The conclusion, therefore, is that a properly functioning chip detector with the increased power to the detector has at most a negligible effect on the oil.

However, in several cases, a black, sludgelike material formed in the gap around the detector and rendered its "zapping" function inoperative. We have determined only that the iron level in the sludge is high.

#### RECOMMENDATIONS

It is proposed that an effort be made to generate sufficient quantity of the sludgy material to characterize it, and, perhaps, determine the mechanism



leading to its creation and deposition, and, if this condition is peculiar to a single brand of oil, or all the oils we are testing. To this purpose we have developed and forwarded to the Commander, USA AVRADCOM, and the contracting officer a proposal, unsolicited, 05-1204, for this work.

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